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MOSER IP LAW GROUP / APPLIED MATERIALS, INC.
1030 BROAD STREET
2ND FLOOR
SHREWSBURY, NJ 07702

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BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

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*Ex parte* ELIZABETH G. PAVEL,
MARK N. KAWAGUCHI, and JAMES S. PAPANU,
Appellants

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Appeal 2008-4297
Application 10/776,672[1]
Technology Center 1700

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Decided: September 29, 2008

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Before EDWARD C. KIMLIN, THOMAS A. WALTZ, and
MARK NAGUMO, *Administrative Patent Judges*.

NAGUMO, *Administrative Patent Judge.*

DECISION ON APPEAL

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[1] Application 10/776,672, *Method and Apparatus for Performing Hydrogen Optical Emission Endpoint Detection for Photoresist Strip and Residue Removal*, filed 11 February 2004. The specification is referred to as the "672 Specification," and is cited as "Spec." The real party in interest is listed as Applied Materials, Inc. (Supplemental Appeal Brief filed 2 November 2007) Br. 2.)

## A. Introduction

Elizabeth G. Pavel, Mark N. Kawaguchi, and James S. Papanu ("Pavel") timely appeal under 35 U.S.C. § 134(a) from the final rejection of claims 1, 2, 6, 7, 9, 14, 16, 17, 21, 22, 28, and 30-45, which are all of the pending claims. We AFFIRM.

The subject matter on appeal relates to processes of removing or etching photoresist from a substrate by a plasma.

Claims 1 and 35 are representative:

> Claim 1
> A method of removing a photoresist layer comprising:
>
> positioning a substrate comprising a photoresist layer into a processing chamber;
>
> removing the photoresist layer using a plasma;
>
> monitoring the plasma for both a byproduct optical emission and a reagent optical emission during the process; and
>
> stopping the etching upon the byproduct optical emission obtaining a first level and the reagent optical emission obtaining a second level.

(Claims App., Br. 10, indentation added.)

> Claim 35
> A method of etching a photoresist layer comprising:
>
> providing a substrate comprising a photoresist layer to a process chamber;
>
> etching the photoresist layer using a plasma;
>
> determining an early endpoint indicator by monitoring the plasma for a reagent optical emission while etching; and

> determining a final endpoint indicator by monitoring the plasma for a byproduct optical emission while etching.

(Claims App., Br. 12, indentation added.)

Independent claim 16 is similar to claim 35, but in place of the two "determining" steps, recites only "monitoring the plasma for both a byproduct optical emission and a reagent optical emission while etching." (Claims App. , Br. 11.)

Grounds of Rejection:

The Examiner has maintained the following grounds of rejection:[2]

A. Claims 1, 7, 9, 16, 21, 22, and 31-45 stand rejected under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara[3] and Powell. [4]

B. Claims 2, 6, 14, and 17 stand rejected under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara, Powell, and Hallock[5]

C. Claims 28 and 30 stand rejected under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara, Powell, and Smith[6]

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[2] Examiner's Answer mailed 22 January 2008 ("Ans.").

[3] Shigenori Ishihara, *Organic Substance Removing Methods, Methods of Producing Semiconductor Device, and Organic Substance Removing Apparatuses*, U.S. Patent Application Publication US 2001/0027023 A1 (2001).

[4] Gary Powell and Richard L. Hazard, *Method and Deice Utilizing Plasma Source for Real-Time Gas Sampling*, U.S. Patent Application Publication US 2002/0135761 A1 (26 September 2002), based on application 10/038,090, filed 29 October 2001.

[5] John Scott Hallock et al., *Process for Removal of Photoresist after Post Ion Implantation*, U.S. Patent Application Publication US 2002/0151156 A1 (17 October 2002), based on application 09/742,721, filed 22 December 2000.

## B. Findings of Fact

Findings of fact ("FF") throughout this Decision are supported by a preponderance of the evidence of record.

672 Specification

1. According to the 672 Specification, semiconductor device fabrication comprises depositing various layers of dielectric, semiconducting, and conducting layers on a silicon substrate, in which features are defined on the substrate by lithography and etching. (Spec. 1:[0003].)

2. In the lithographic and etching steps, a layered substrate is coated with photoresist, the photoresist is patterned, and then the pattern is transferred to the underlying layers during etching using the patterned photoresist as an etch mask. (Spec. 1:[0003].)

3. From this statement, we understand the term "etch" to refer to the transfer of a pattern to the substrate.

4. In the words of the 672 Specification, "[m]any of these etch processes leave photoresist and post-etch residues on the substrate and must be removed before performing the next process step." (Spec. 1:[0003].)

5. From this statement, we infer that an etch process typically removes at least some of the photoresist from the substrate.

6. According to the 672 Specification, the patterned photoresist also serves as an ion implant mask for preferentially doping semiconductor

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[6] Michael Lane Smith, Jr., et al., *Method and Apparatus for Monitoring Plasma Processing Operations*, U.S. Patent 6,419,801 B1 16 July 2002, based on application 90/065,358, filed 23 April 1998.

substrates in selected areas by exposing those areas to ions or electron beams of implant species such as arsenic, boron, phosphorus, or other species. (Spec. 1:[0004].)

7. The ion implantation process is said to dehydrogenate the photoresist material, resulting in a hydrogen deficient, carbonized crust layer. (Spec. 1:[0004].)

8. As a result, the characteristics of the photoresist material are said to vary vertically, and uniform removal ("stripping") of the photoresist from the structure can be difficult. (Spec. 2:[0004].)

9. The 672 Specification identifies a need for a technique for monitoring removal of the photoresist such that the removal process can be controlled as the characteristics of the material change. (Spec. 2:[0004].)

10. Optical emission spectroscopy is said to be commonly used to detect the endpoint of plasma etch processes. (Spec. 2:[0005].)

11. The endpoint is said usually to be based on increasing signal for reactants or decreasing signal for products. (Spec. 2:[0005].)

12. Somewhat more particularly, the 672 specification states that "[t]he endpoint is identified when either the reactants or products attain a specific concentration (i.e., the respective signals cross a threshold level.)" (Spec. 2:[0005].)

13. According to the 672 Specification, however, "such an endpoint detection technique does not account for the variations in the characteristics of a photoresist layer that has been exposed to an ion beam." (Spec. 2:[0005].

14. The 672 describes its invention as comprising the use of the hydrogen optical emission peak to identify the endpoint of a photoresist stripping process. (Spec. 2:[0007].)

15. This is said to be especially useful for crust removal during post-implant photoresist stripping because the hydrogen content of the crust layer is significantly lower than that of the bulk photoresist. (Spec. 2:[0007].)

16. As a result, the entire photoresist removal is said to be monitored in a simpler and more direct manner using the hydrogen signal than using, for example, only an oxygen signal from the reactants. (Spec. 2:[0007] and 3:[0008].)

17. In the embodiments involved in this appeal, at least one additional emission peak, e.g., an oxygen or other reactant signal, or signal from a by-product volatile gas formed from the components of the bulk photoresist is also said to be monitored to provide more robust or flexible endpoint control. (Spec. 3:[0008].)

18. According to the 672 Specification, identification of an early endpoint indicator is provided by monitoring the reagent oxygen peak, and identification of a late/final endpoint indicator is provided by monitoring the by-product hydrogen peak. (Spec. 6:[0026].)

19. Because hydrogen is a by-product peak and oxygen is a reactant peak, the hydrogen and oxygen signals are said to mirror each other, and monitoring both is said to provide a backup, so that if one is missed, the endpoint still can be detected by the other. (Spec. 7:[0026].)

20. In the words of the 672 Specification, "[d]ual wavelength endpoint triggering occurs when either wavelength meets the endpoint conditions." (Spec. 7:[0026].)

21. According to the 652 Specification, "[t]he oxygen emission peak(s) of 777nm and/or 845nm can also be utilized, either singly or jointly in combination with the hydrogen emission peak. The relative intensities of the peaks so measured and monitored could be indicative of the conditions of the plasma sources and chamber surfaces and be used to provide a proper 'fingerprint' of a clean or 'golden' chamber." (Spec. 10:[0039].)

Ishihara

22. Ishihara relates to processes of removing a photoresist having an ion-implanted region from a semiconductor wafer in a chip manufacturing process. (Ishihara 1:[0002].)

23. Ishihara teaches that "when a photoresist used as a mask material during local ion implantation is to be removed, since the photoresist has become difficult to be ashed because the implanted ions deteriorate (or affect) or *harden* the vicinity of the surface of the photoresist, the removal of the photoresist takes a long time." (Ishihara 1:[0008]; emphasis added.)

24. We understand Ishihara to be teaching that ion implantation in the photoresist results in the formation of a crust on the photoresist that is hard to remove by conventional techniques.

25. According to Ishihara, such a photoresist is normally removed ("ashed") by reaction with a plasma of oxygen containing a carbon-fluoride

based gas that converts the ion species into volatile compounds with active species of fluorine. (Ishihara 1:[0012].)

26. Areas of the substrate that are not coated with photoresist, however, may be corroded by exposure to the active species of fluorine. (Ishihara 1:[0012].)

27. Ishihara provides a two-step process to remove the photoresist while suppressing the corrosion of areas of the substrate not covered with the photoresist. (Ishihara 2:[0019].)

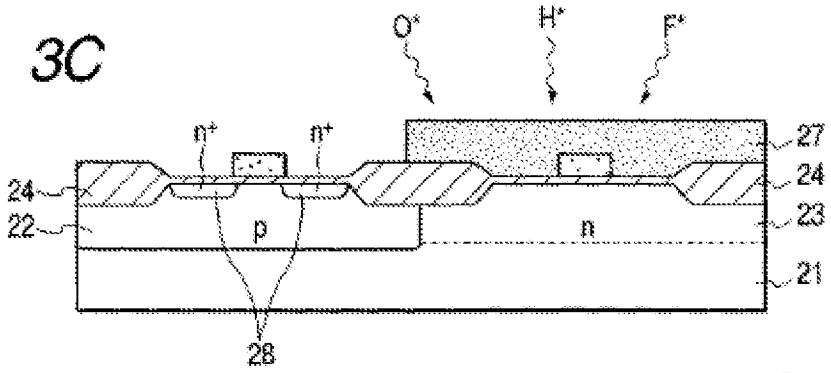
28. In an embodiment, a photoresist is coated on the surface of a semiconductor substrate, exposed with a pattern, and developed (Ishihara 5:[0116]); such a structure is shown in Ishihara Figure 3A (see Ishihara 7:[0155]).

29. The substrate is then ion-implanted with arsenic, phosphorus, boron, or similar materials (Ishihara 5:[0116]); such a structure is shown in Ishihara Figure 3B (see Ishihara 7:[0157]).

30. The substrate, which contains exposed semiconductor areas, areas covered by photoresist, and areas covered by ion-implanted (i.e., crusted) photoresist, is then exposed in a "first mode" to a plasma generated in an atmosphere comprising an oxygen-containing gas, a hydrogen-containing gas, and a fluorine-containing gas (Ishihara 6:[0119].)

31. Ishihara Figure 3C (described at Ishihara 7:[0160]), reproduced below, shows the structure:

FIG. 3C




{Ishihara Figure 3C is said to show a step in the process}[7]

32. According to Ishihara, the ion-implanted regions **27** of the photoresist are modified by a plasma treatment process in a "first mode" to make it feasible to remove the resist by treatment in a "second mode" using a less corrosive plasma generated from, e.g., only an oxygen-containing gas. (*See* Ishihara 6:[0130].)

33. In the first mode, Ishihara teaches that because "the implanted ion species of phosphorus, arsenic, or the like turn into fluoride or hydrides to disappear in the first step, there appears no residue of the implanted ion species." (Ishihara 7-8:[0162].)

34. Ishihara also indicates that during the first mode, "[t]he region [of the photoresist] deteriorated by the ion implantation may be removed at the same time as this processing or may be only modified without being removed." (Ishihara 7:[0160]).)

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[7] The text in curly braces following the Figures is provided to ensure compliance with section 508 of the U.S. Rehabilitation Act for publication of this Decision on the USPTO website pursuant to the Freedom of Information Act. It is not part of the Decision.

35. Ishihara teaches that the switch from mode 1 to mode 2 can be based on a signal from an in-situ monitor, such as monitoring "the light emission caused by CO [309 nm] and H [656 nm] as products from the resist or by O [777 nm] from the added gases . . . ." (Ishihara 6:[0135]; emission wavelengths reported at 6:[0136].)

36. In the second mode, the residual photoresist is removed by a plasma that does not disturb areas of the semiconductor device not covered by a layer of photoresist. (Ishihara 6[0137].)

Powell

37. Powell teaches methods of monitoring the conditions in a reaction chamber **101** by removing samples of the gases and analyzing their contents by emission spectroscopy of a plasma generated from the gases in a side excitation chamber **105**. (Powell 1:[0018] and Powell Figure 1.)

38. Powell indicates that multiple peaks from multiple spectral regions can be monitored at the same time, leading to enhanced effective signal to noise ratio and better reaction endpoint detection. (Powell 4:[0030].)

39. In Figure 11, Powell reports an example of monitoring the condition of a chamber during treatment with an oxygen plasma, in which emission from several species, e.g., oxygen at 777 nm, hydrogen at 656 nm, and CO at 483 nm and at 520 nm, as well as fluorine and nitrogen, are monitored. (Powell 7:[0051]): Figure 11 is shown below:

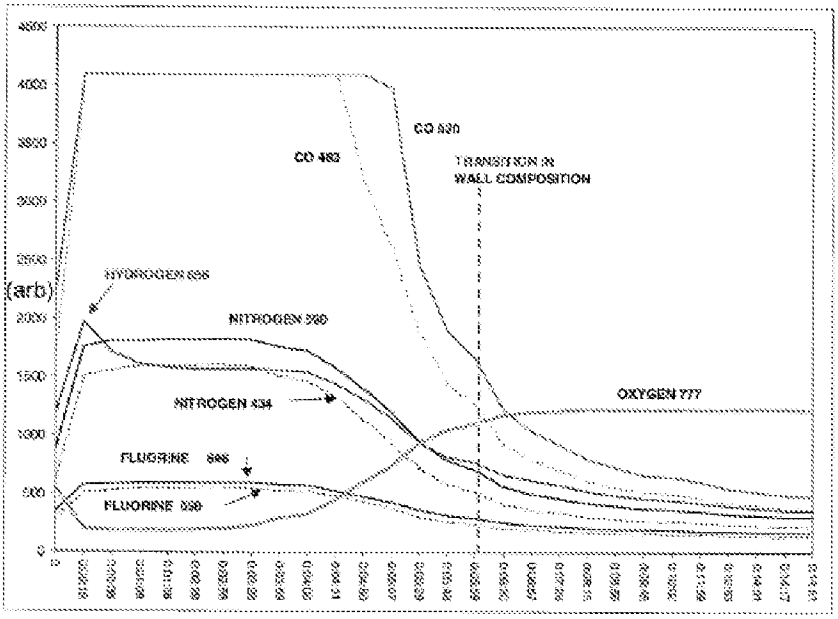


Figure 11

{Powell Figure 11 is said to show the emission of plasma components with time}

40. In Powell's words, Figure 11 shows that "[a]t approximately 5[minutes]:29[seconds], the carbon monoxide production begins to drop steeply, as indicated by the peak centered at about 520 nm. At about the same time, oxygen concentration increases, as indicated by the peak centered at about 777 nm." (Powell 7:[0051].)

41. Powell continues, "[t]he combination of decreased carbon monoxide production and increased oxygen concentration indicates a depletion of carbon from the chamber by the oxygen plasma." (Powell 7:[0051].)

42. Powell remarks further that "[m]onitoring depletion of materials from a chamber during cleaning enables timing, control, and validation of the cleaning process." (Powell 7:[0051].)

43. Powell teaches further that:

> [t]he monitoring may look for transitions in wall chemistry or a predetermined chamber condition, based on a profile of a prior chamber condition. The profile can include selected peaks, selected bands, or a fall [sic: full?] spectrum in a predetermined range. Analysis can be based, for instance, on peaks, spectral differences or asymptotic changes in peaks or spectral differences."

(Powell 7:[0051].)

## C. Discussion

The burden is on Pavel, as the Appellant, to demonstrate reversible error in the Examiner's rejections. *See, e.g., In re Kahn*, 441 F.3d 977, 985-86 (Fed. Cir. 2006) ("On appeal to the Board, an applicant can overcome a rejection [under § 103] by showing insufficient evidence of *prima facie* obviousness or by rebutting the *prima facie* case with evidence of secondary indicia of nonobviousness.") (quoting *In re Rouffet*, 149 F.3d 1350, 1355 (Fed. Cir. 1998)).

The Examiner finds that Ishihara describes a process of etching or removing a photoresist layer that meets all the limitations of claims 1, 16, and 35 but for the explicit monitoring of both a reagent and a by-product optical emission; and (for claim 1) stopping the etching at certain signal levels of each (Ans. 3); and (for claim 35) determining an early endpoint by monitoring a reagent optical emission and determining a late endpoint by monitoring a by-product optical emission. The Examiner finds, however,

that Ishihara "clearly disclose[s that] it is possible to monitor [a] plurality of emission[s] at the same time in order to control the endpoint (i.e. switching time)." (*Id.* at 4.) Moreover, the Examiner finds that Ishihara teaches that reagent (oxygen) emission and by-product (carbon monoxide, CO, and hydrogen) emissions may be monitored. (*Id.*) The Examiner finds that Powell teaches monitoring optical emissions from multiple species in a plasma. (*Id.*) The Examiner concludes that it would have been obvious to a person having ordinary skill in the art to monitor both reagent and by-product emissions in order to obtain more accurate evaluation of the progression of the plasma recipe and the endpoint. (*Id.*)

Pavel emphasizes that Ishihara does not teach monitoring both a by-product emission and a reagent emission. (Br. 4.) Pavel argues that combining the teachings of Ishihara and Powell would result in a process in which a plasma would be formed and monitored external to the process chamber. Accordingly, Pavel denies that a prima facie case of obviousness has been established for any of the claims. (Br. 5.)

This argument misapprehends the rejection. We do not understand the Examiner to have suggested that a person having ordinary skill in the art would have adapted the entire apparatus described by Powell to perform the process described by Ishihara with simultaneous observation of optical emissions from multiple species. *See, e.g., In re Keller*, 642 F.2d 413, 425 (CCPA 1981) ("The test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference; . . . Rather, the test is what the combined teachings of the references would have suggested to those of ordinary skill in the art."). In the present case, the ordinary worker would have learned from Powell, if it

was not already appreciated from Ishihara, that the emission spectra of plural species, including reagents and by-products, could have been advantageously monitored simultaneously to indicate when to stop a given plasma reaction. Powell's teaching in paragraph 51 that "[t]he combination of decreased carbon monoxide production and increased oxygen concentration indicates a depletion of carbon from the chamber by the oxygen plasma" (FF 40) would have been particularly relevant, as Ishihara teaches an oxygen reagent and carbon monoxide as a product of reaction of the photoresist with the oxygen plasma. Pavel has failed to show reversible error in the Examiner's rejection of claims 1 and 16.

Pavel objects further to the Examiner's conclusion that monitoring the reagent (oxygen) and by-product (CO) emissions suggested by Ishihara, and the simultaneous monitoring suggested by Powell, would have suggested the early endpoint indicator and the final endpoint indicator required by claim 35, as well as by claims 42 and 43, which depend from claims 1 and 16, respectively. (Br. 5.) We are not persuaded, as we are confident that the teachings of Powell would have suggested to the ordinary worker that the reactant emission signal and by-product emission signal would have provided indications, in the Ishihara process, that the first mode was nearing the end. Moreover, as shown in Figure 11, it appears that the reactant signal approaches its asymptotic value sooner than the by-product emission signal. Thus, the reactant signal would have provided an "early endpoint indicator" as recited in claim 35. Similarly, the ordinary worker would have understood that the by-product signal would have provided a later indication that the first mode was complete. This corresponds to the "final endpoint indicator" required by claim 35. The level of skill in the art is quite high, as

indicated by the sophistication of the prior art references. There is nothing to suggest that applying a correlation derived from an example of cleaning a chamber (Powell paragraph [0051]) to another example of etching or removing photoresist from a semiconductor (Ishihara Figure 3C, reproduced *supra*) would have been beyond the ordinary worker. Thus, Pavel has not shown reversible error with regard to the rejection of claims 35, 42, or 43.

Claims 31, 33, and 39 (determining a condition of the plasma source)

The Examiner finds that Powell teaches determining the condition of the plasma source (Ans. 5, citing Powell Figures 5, 6, 9, and 10, and paragraphs [0028]-[0032]) and concludes that claims 31, 33, and 39 would have been obvious. Pavel denies that there is any such teaching in these passages and urges that the rejection of these claims be reversed. (Br. 6-7.) In rebuttal, the Examiner maintains that "the condition of the plasma source comprises any condition that [is] related to the plasma source including emission spectrum, wavelength, and gas flow rate of the plasma." (Ans. 9.) Such conditions, the Examiner maintains, are determined by Powell. (*Id.*) Pavel, in the Reply Brief,[8] cites the disclosure in the 672 Specification that relative intensities of oxygen and hydrogen peaks can be monitored and could be indicative of conditions of the plasma source. (Reply Br. 6; *cf.* FF 19.) Pavel asserts that this passage from the 672 Specification indicates, without reading limitations into the claims, that the "condition" means "a state of health of the plasma source." (Reply Br. 6.)

It is fundamental that "during examination proceedings, claims are given their broadest reasonable interpretation consistent with the

[8] Reply Brief filed 22 April 2008, ("Reply Br.").

specification." *In re Hyatt*, 211 F.3d 1367, 1372 (Fed. Cir. 2000). As Pavel recognizes, it is improper to read limitations from preferred embodiments in the specification into the claims. *In re Am. Acad. of Sci. Tech. Ctr.*, 367 F.3d 1359, 1369 (Fed. Cir. 2004). The Examiner's conclusion that determining any condition related to the plasma source is within the scope of "determining a condition of a plasma source" is not inconsistent with the description in the 672 Specification that the relative intensities of various peaks "could be indicative of the conditions of plasma sources." (Spec. 10:[0039]; FF 21.) Nor is the Examiner's conclusion inconsistent with Pavel's assertion (Reply Br. 6) that "condition" here means "health," as both terms are so broad in the context of plasma sources that ascertaining that a plasma exists falls within the ambit of the term. Powell's teachings go far beyond that level of determining characteristics—i.e., "conditions"—of the plasma, and hence of the plasma source. Accordingly, we are not persuaded that the Pavel has demonstrated reversible error in the Examiner's rejection of claims 31, 33, and 39.

Claims 41, 44, and 45 (cleaning cycle or components degrading)

Claims 41, 44, and 45 depend from upon claims 1, 16, and 35, respectively, and add the further limitation that a determination be made from a monitored optical emission whether a cleaning cycle is necessary or whether components within the chamber are degrading. The Examiner finds that Powell teaches determining the condition of the processing chamber in paragraphs [0051]-[0053] (Ans. 5) and concludes that it would have been obvious to the ordinary worker to adapt the processes taught by Ishihara to include determining whether the chamber needs cleaning (*id.* at 6).

Appellant objects that Powell teaches monitoring optical emissions from an external process effluent. (Br. 7.) Pavel argues further that the portion of Powell relied on by the Examiner provides "a chamber clean [sic] process that may be monitored to determine when the chamber clean [sic] is complete—not whether a chamber clean is necessary to begin with." (*Id.*) Pavel urges that no prima facie case of obviousness has been established. (*Id.*)

These arguments are without merit. Powell teaches that "[p]lasma etch reactors experience a build up of polymers and other etch byproducts, which periodically must be cleaned or removed." (Powell 7:[0052].) The cleaning process described in paragraph [0051] involves monitoring oxygen and carbon monoxide signals–signals that Ishihara recommends monitoring. The knowledge that plasma etch reactors need periodic cleaning coupled with the observation of the same signals during processing substrates that are monitored during cleaning would have suggested to the person having ordinary skill in the art that those same signals could have been used to signal the need for cleaning.

Moreover, the process taught by Ishihara involves degrading a component within the chamber, namely, the ion-implanted photoresist, and monitoring the degradation. (FF 31-35.) Thus, Ishihara teaches determining from optical emissions whether a component in the chamber is degrading. We have already determined that monitoring both a reactant emission signal and a by-product emission signal during the process would have been obvious. Hence, any error in the Examiner's reliance on Powell would have been harmless regarding the obviousness of claims 41, 44, and 45.

Rejections B (Hallock) and C (Smith)

Pavel does not contest the findings of the Examiner regarding Hallock (Ans. 6) and Smith (Ans. 7). (Br. 8-9.) Rather, Pavel argues that neither reference cures the alleged defects of Ishihara and Powell, and that a prima facie case of obviousness has not been established. (*Id.*)

As we have held that Pavel has not shown reversible error in the Examiner's rejection of the independent claims, we find these later arguments unpersuasive of reversible error.

## D. Summary

In view of the record and the foregoing considerations, it is:

ORDERED that the rejection of claims 1, 7, 9, 16, 21, 22, and 31-45 under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara and Powell is AFFIRMED;

FURTHER ORDERED that the rejection of claims 2, 6, 14, and 17 under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara, Powell, and Hallock is AFFIRMED;

FURTHER ORDERED that the rejection of claims 28 and 30 under 35 U.S.C. § 103(a) in view of the combined teachings of Ishihara, Powell, and Smith is AFFIRMED; and

FURTHER ORDERED that no time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a).

**AFFIRMED**

ack

cc:

Moser IP Law Group / Applied Materials, Inc.
1030 Broad Street
2nd Floor
Shrewsbury, NJ 07702